CSP State of the Art and New Developments, the DLR vision

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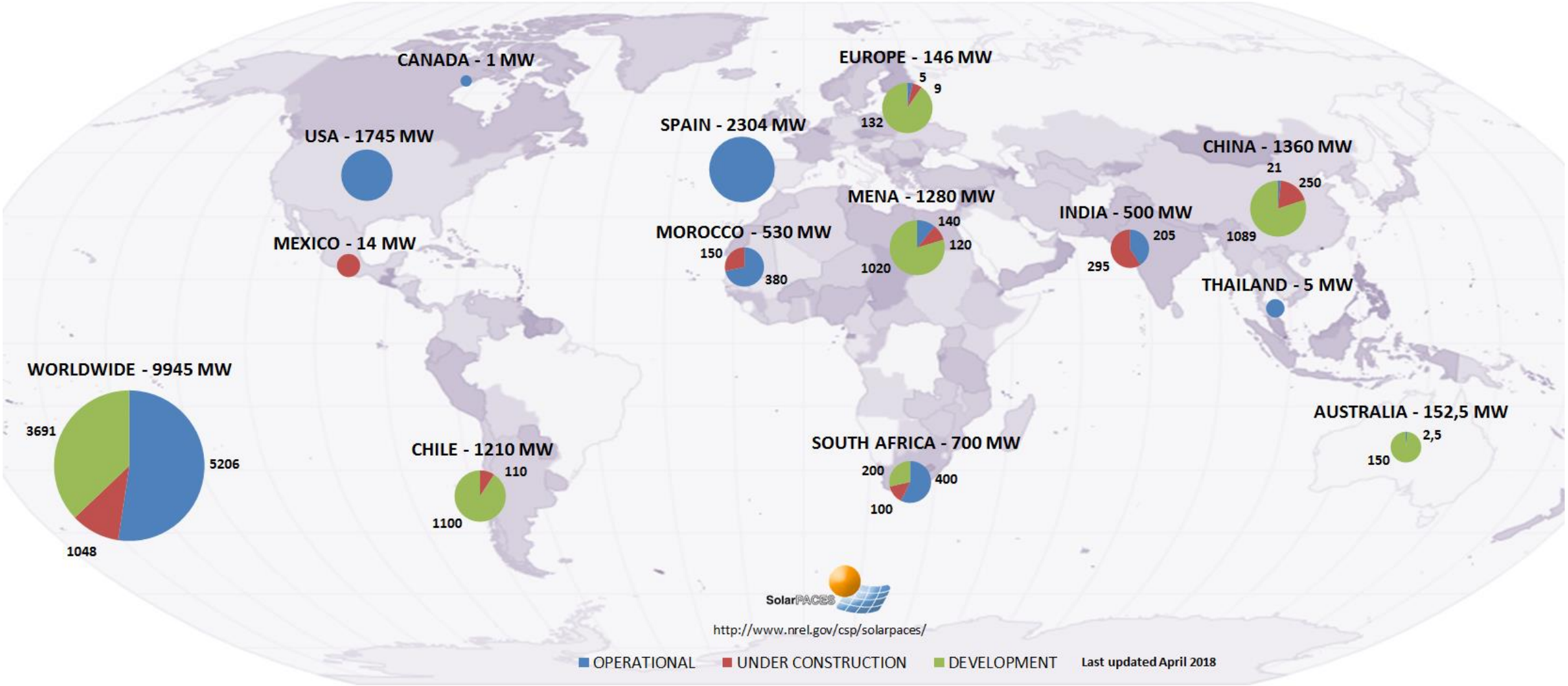
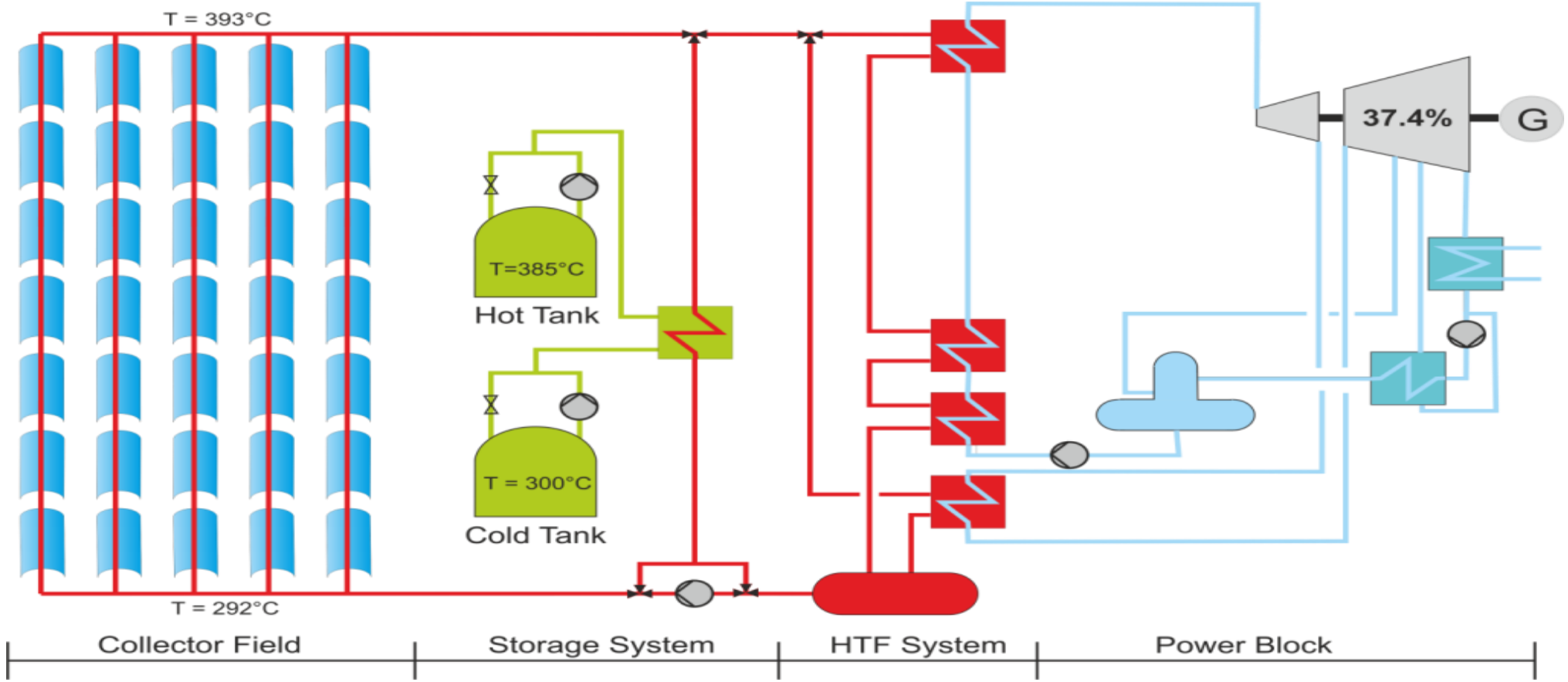
Concentrating Solar Power Market



State of the art parabolic trough plant

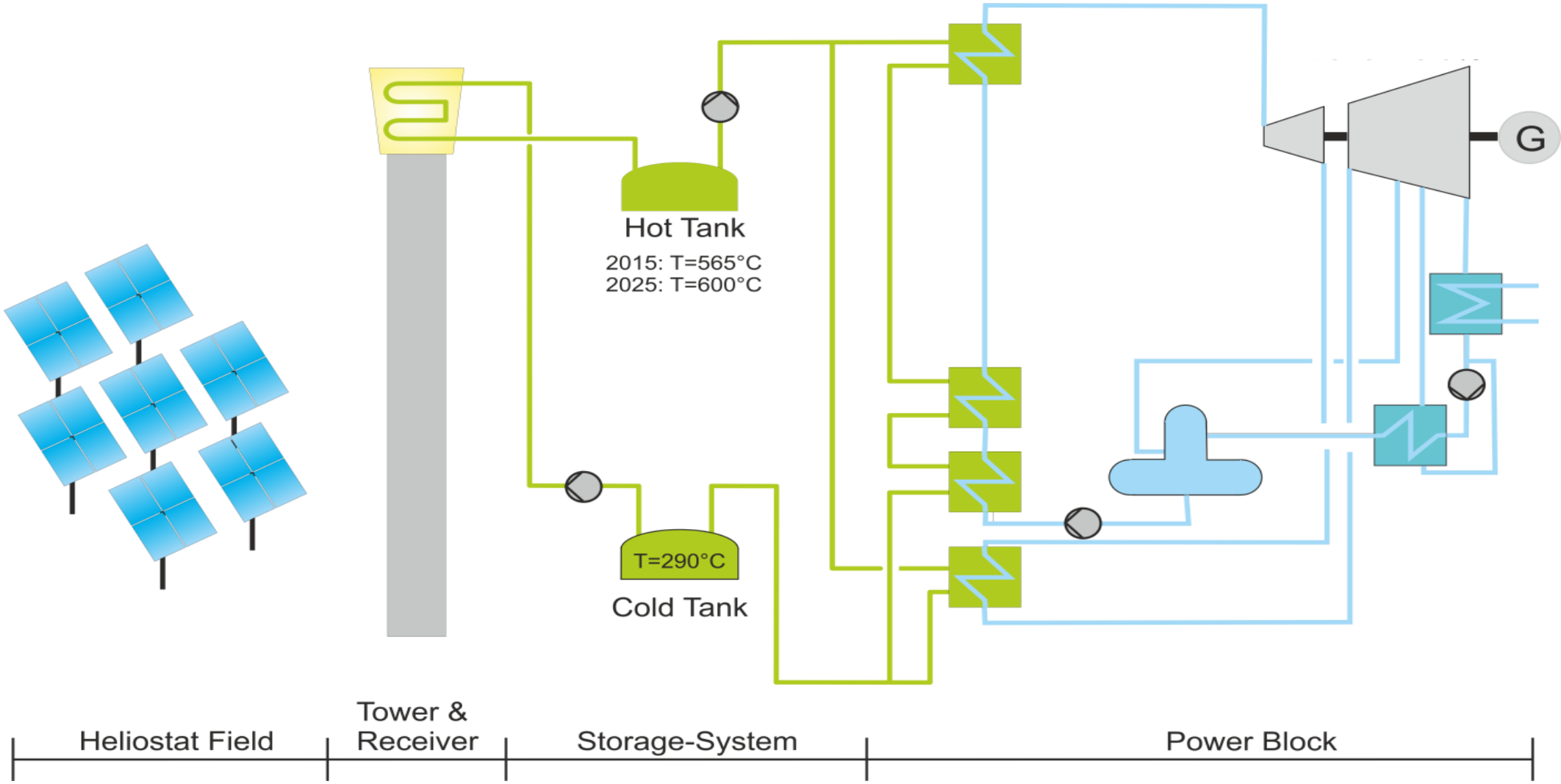


Commercial Parabolic Trough Technology
Solana, Arizona, USA

- Thermal Oil
- 280 MWe
- 6h storage (molten salt)

Abengoa

State of the art solar tower plant

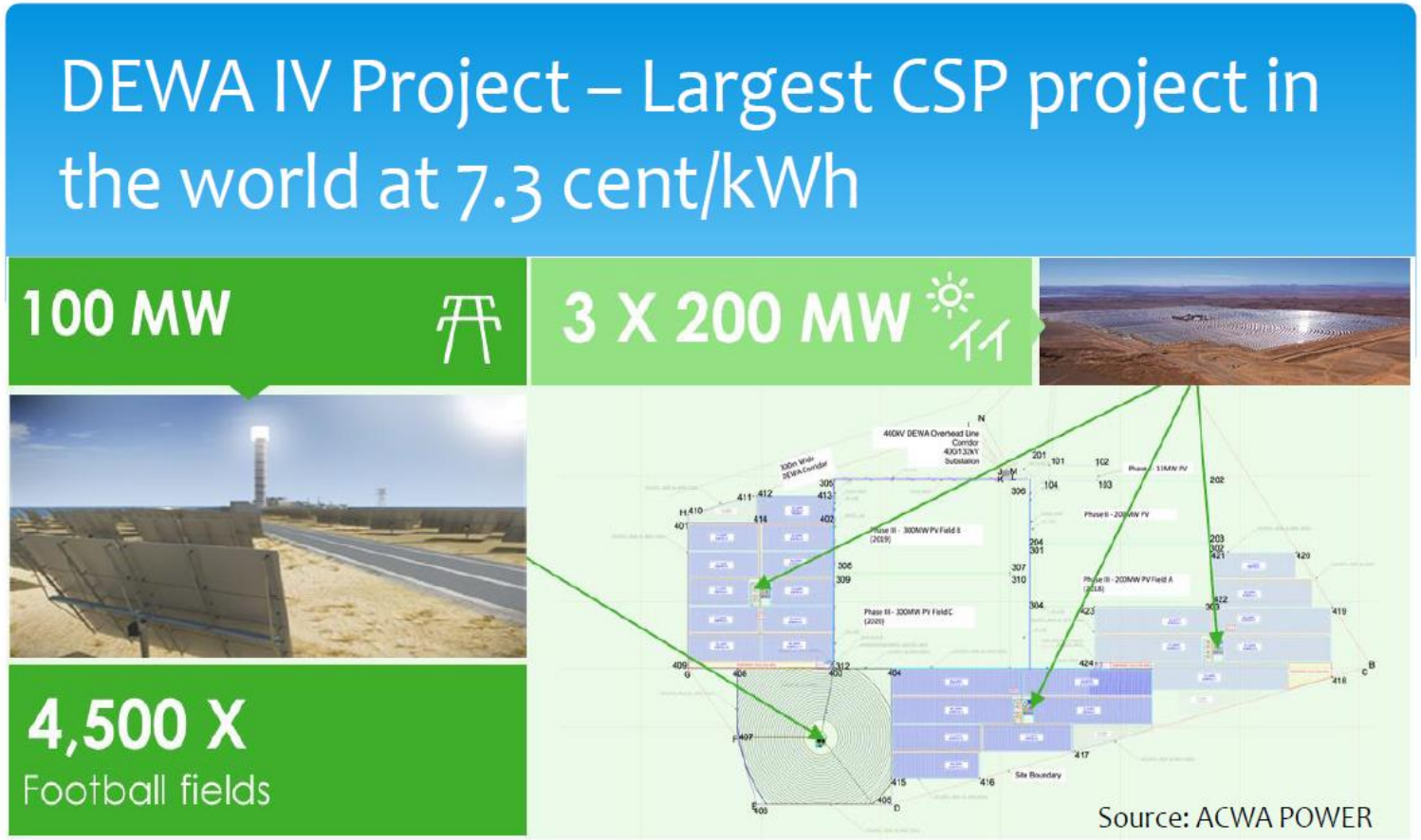


Commercial Tower Technology
Crescent Dunes / Tonopah, Nevada, USA

- Molten Salt
- 110 MWe
- 10 h Storage

Solar Reserve

CSP Status



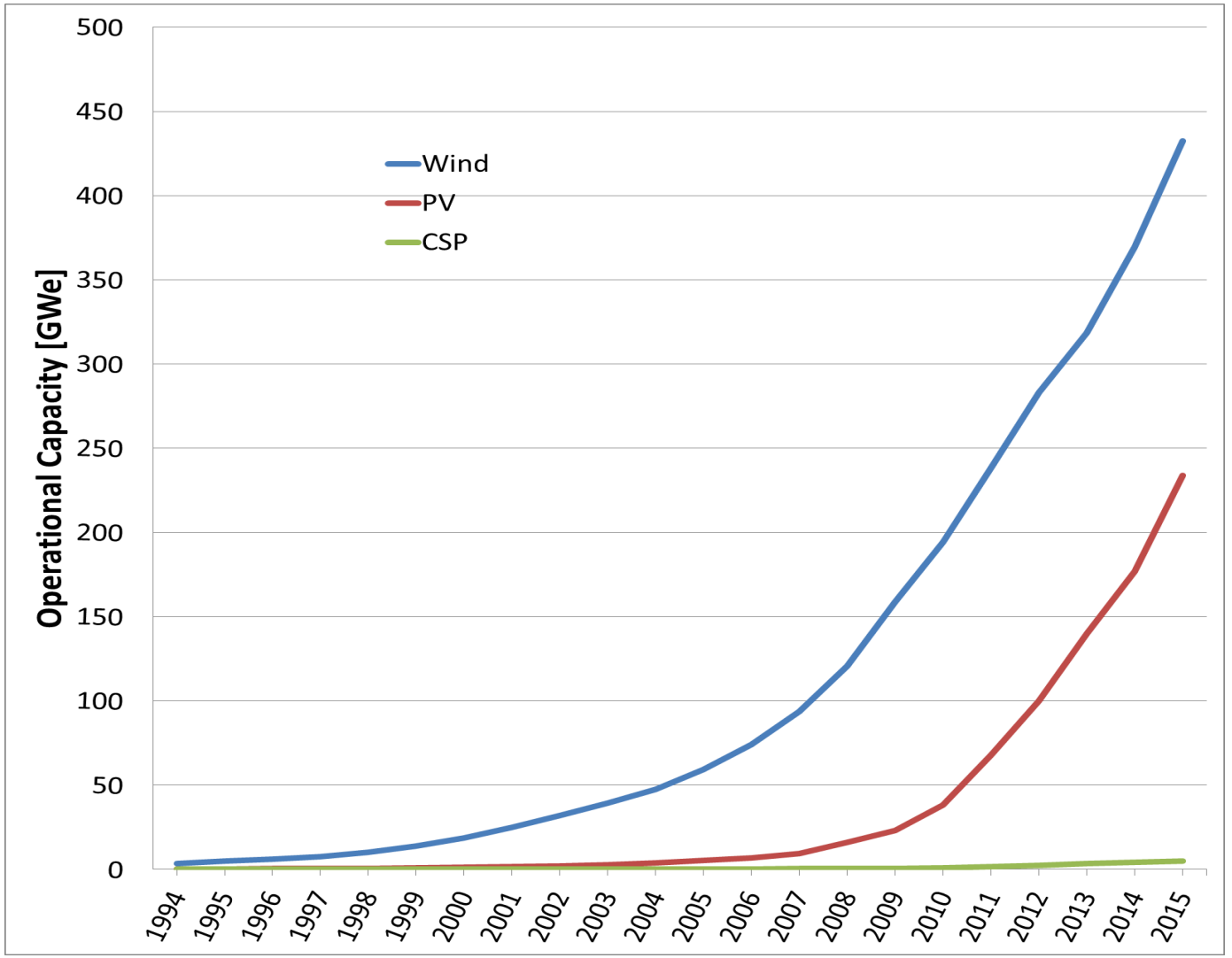
7,3$CentS/kWh (10h storage) combined with PV for 3$Cents/kWh

→ **5€Cents/kWh for dispatchable power: competitive with gas turbine plants**

CSP in the worldwide power market

Installed capacity by 2016:
CSP: 5 GW
Geothermal 14 GW
Biomass: 111 GW
PV: 304 GW
Wind: 487 GW
Hydro: 1.103 GW

Total generating capacity worldwide (2016): 6.473 GW



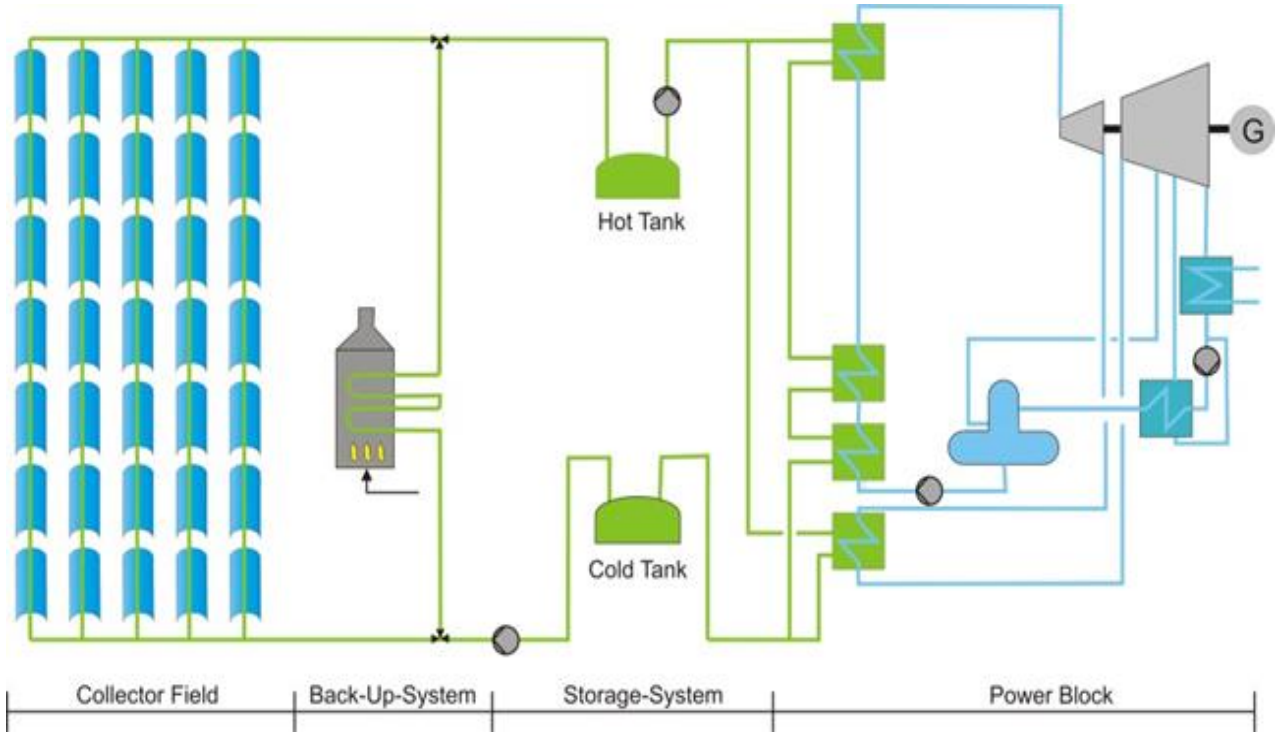
CSP assessment:
Still at beginning of the learning curve
Unique selling point: dispatchable power

- Thermal Storage
- (renewable) Fuel back-up

CSP options to improve competitiveness

- **Efficiency increase**
  - Increased temperature
    - New heat transfer media
    - New power cycles
- **Solar field cost reduction**
  - Collector design optimization
    - Heliostat optimization
    - New Parabolic trough design
- **Improved operation and maintenance**
  - Optimized control and operating strategies
    - Dynamic modelling, Control and operation optimization
    - Reduction of water consumption
- **Improved financing conditions – “bankability”**
  - Reduce risks and uncertainties
    - Quality assurance and standards

New Heat Transfer Media: Molten salt in parabolic trough collectors



10 major concerns:

1. Filling and draining of the plant
2. High thermal effort during anti-freeze operational mode
3. Danger of freezing during various operation modes
4. Blackout scenarios
5. Material requirements, high corrosion
6. Performance of the SCA / HCE
7. Flexible connection: Proof of functionality and tightness
8. Steam Generating System: internal leakages
9. Maintenance procedures, Handling of disturbances
10. Stability of salt mixtures

Demonstration plant under costruction at Évora, Portugal

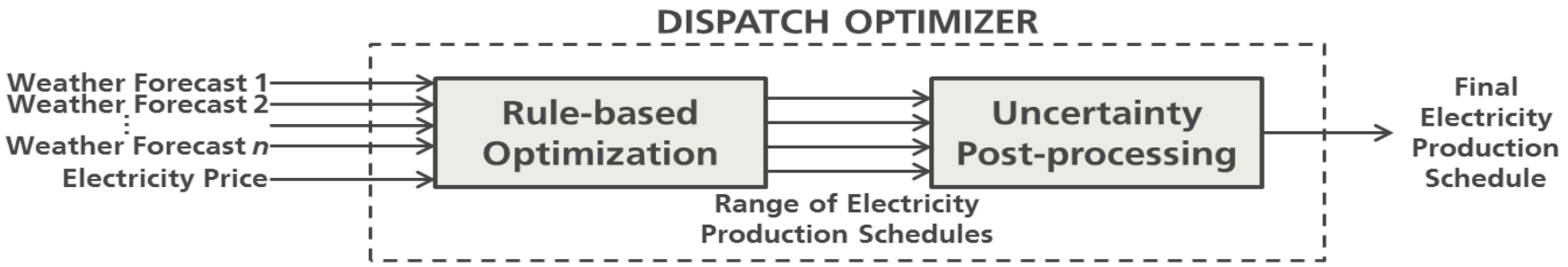
Improved Operation and Maintenance: Dispatch Optimizer

Concept:

- Optimization of electricity production schedule based on
  - Actual plant status (availability, mirror cleanliness etc.)
  - Electricity market prediction
  - Weather forecast
- Special feature: accounting for uncertainties in the forecast

Motivation:

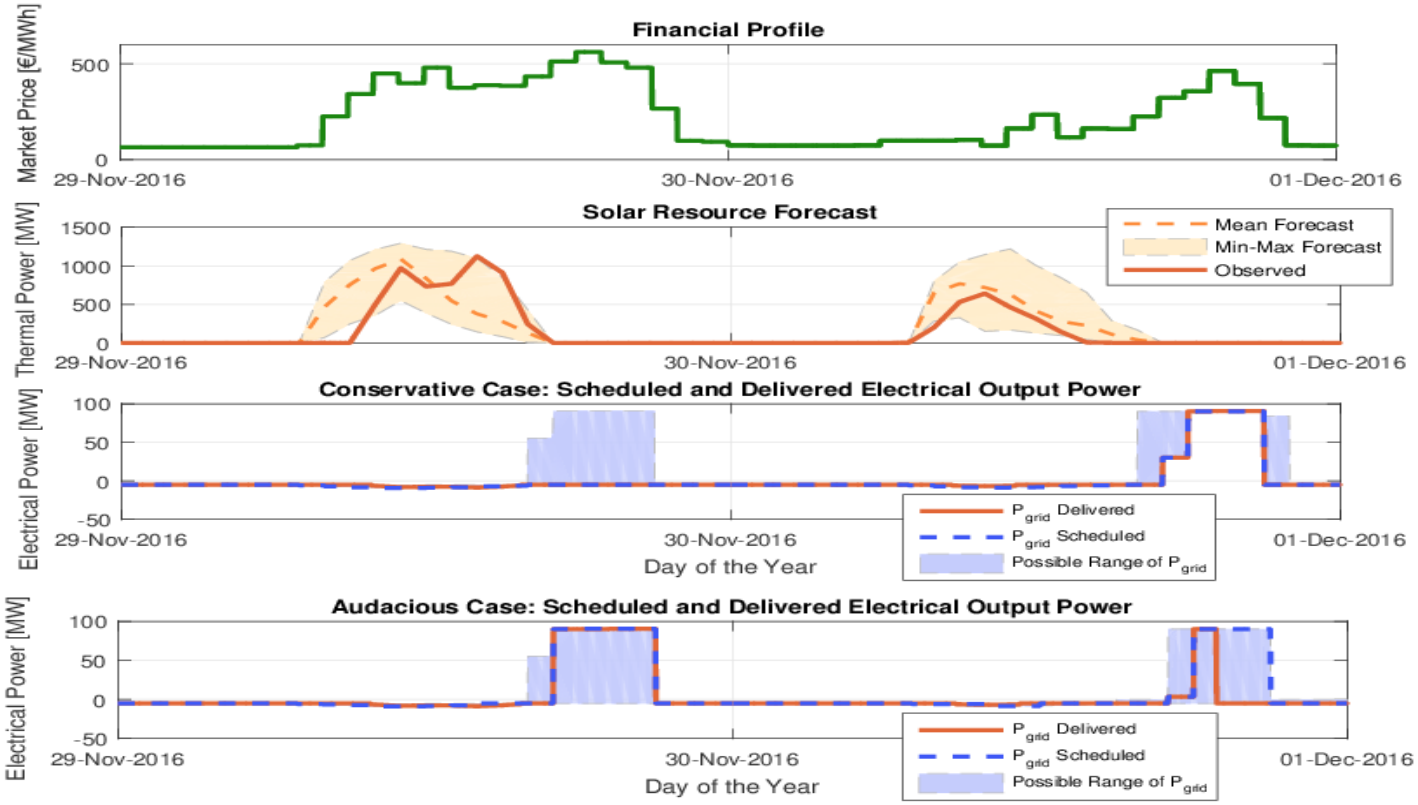
- Increase economic benefit of integrated thermal storage



Dispatch optimizer

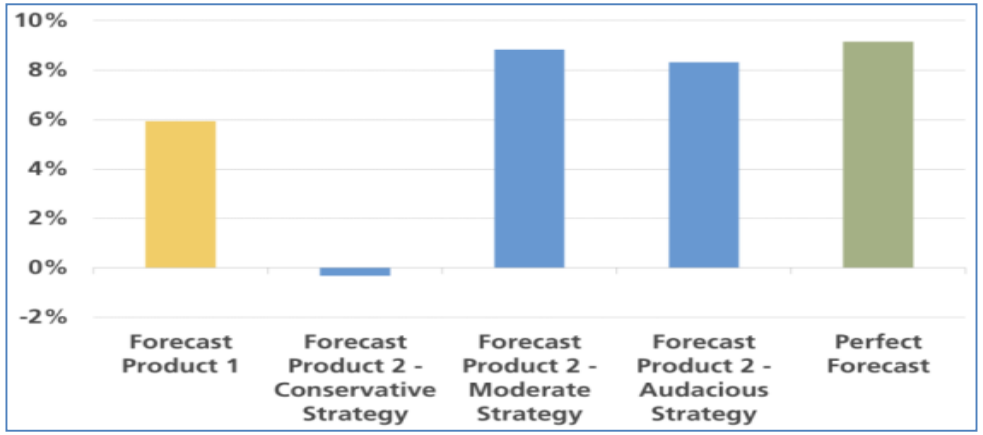
How does it work?

Simulation results for two days

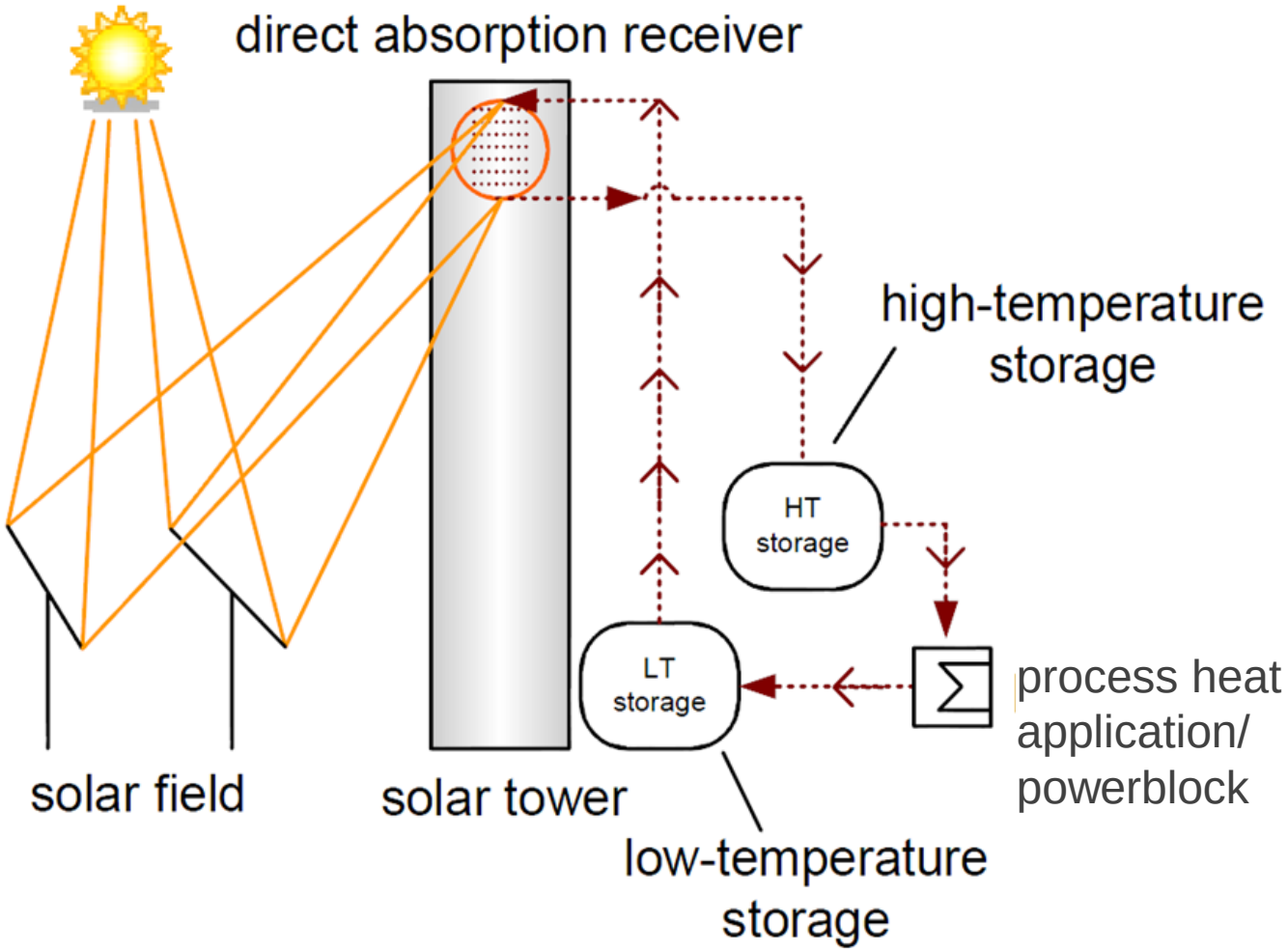


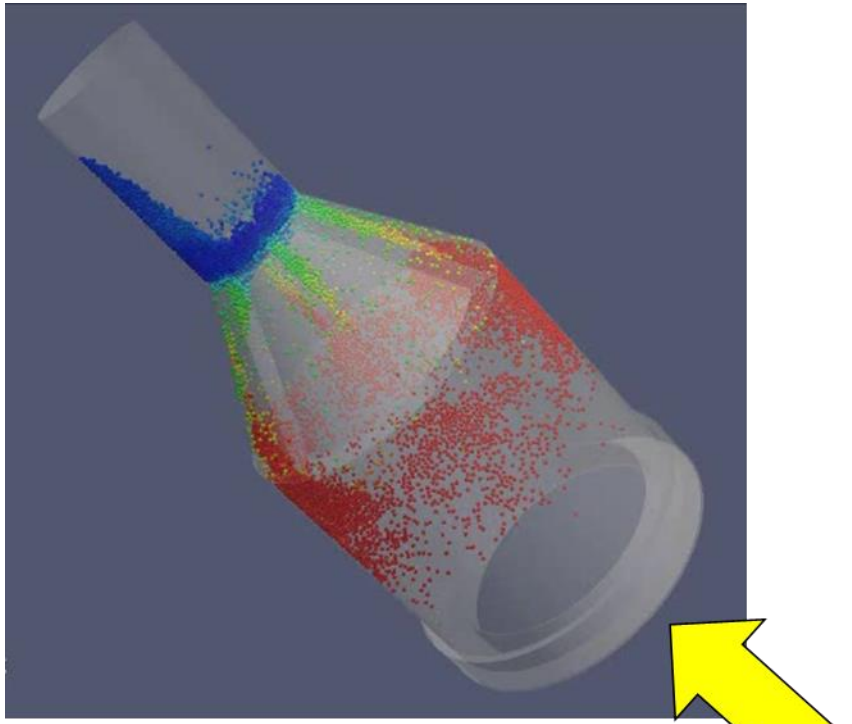
Improvement of annual operating income

- Benchmark: Production schedule based on trivial weather forecast (the weather today will be like yesterday)



Direct Absorption Particle Receiver CentRec®





System Description - Receiver

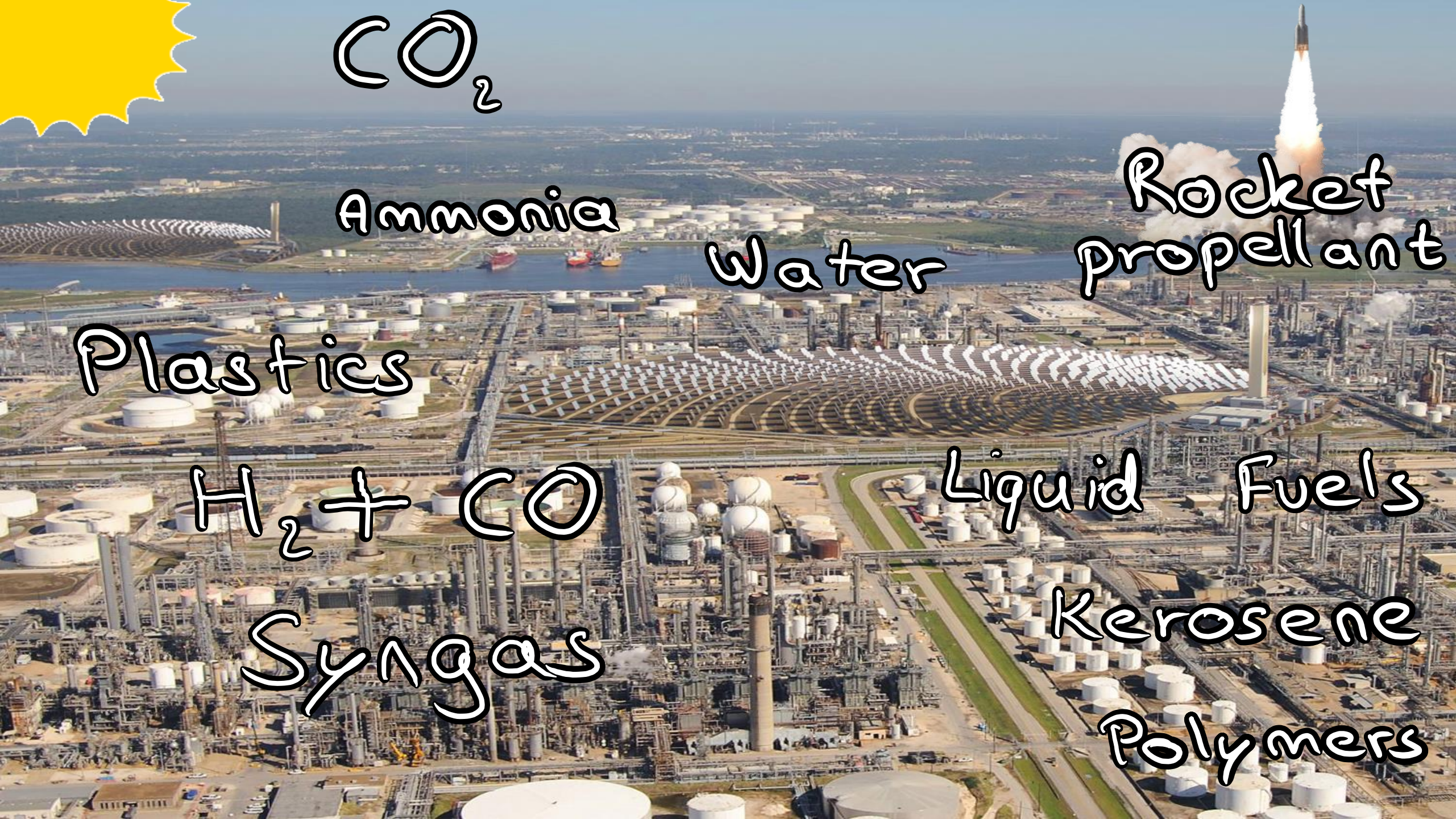
- Particle residence time / receiver outlet temperature controlled by adjusting rotational speed
- Thin, optical dense layer for all load conditions

Aperture area and diameter		1 m², 1.13 m
Rotation axis inclination		45°
Thermal power	Validation test setup	500 kW_{th}
	Commercial setup	2,500 kW_{th}
Receiver outlet temperature	Minimum	900°C
	Design	1,000°C
Particle mass flow at 2,500 kW_{th}, 200°C/ 900°C receiver inlet/ outlet temperature		3 kg/s
Rotational speed		aprox. 45 rpm

DLR large scale testfacilities

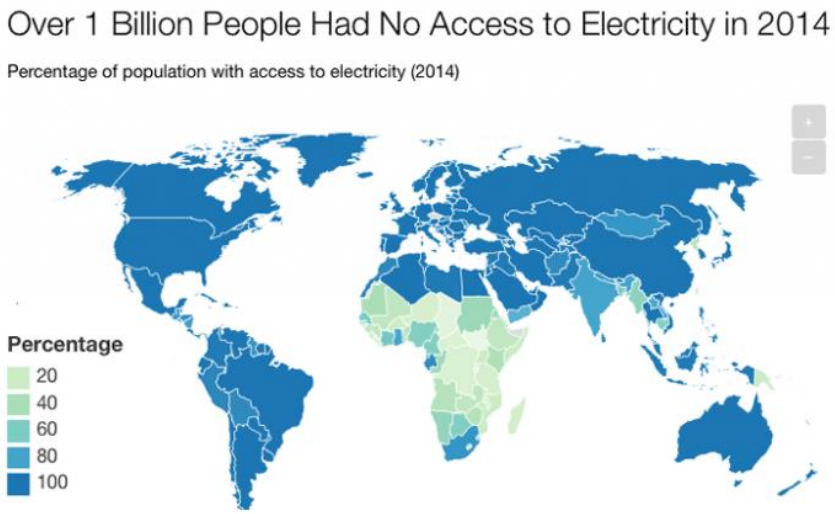
- Solar furnace and simulator in Cologne (~ 20 kW_{th})
- 1,5 MW_e solar tower plant for system and components test and demonstration
- Research platform für up to 500 KW_{th} experiments
- Synlight: world largest artificial sun for experiments up to 400 kW_{th}
- Future plans: Multifocus tower to provide additional research platforms with up to 2.000 kW_{th} (available summer 2020)

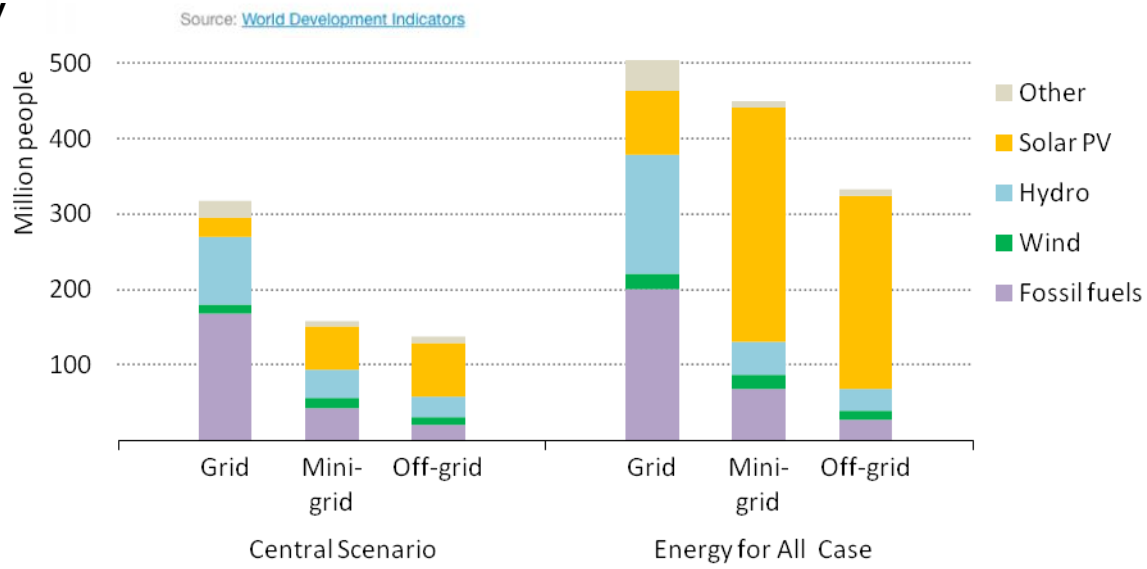

Artist‘s view


CO_2
Ammonia
Water
Rocket propellant
Plastics
H_2 + CO
Syngas
Liquid Fuels
Kerosene
Polymers

Potential market decentralized energy supply?

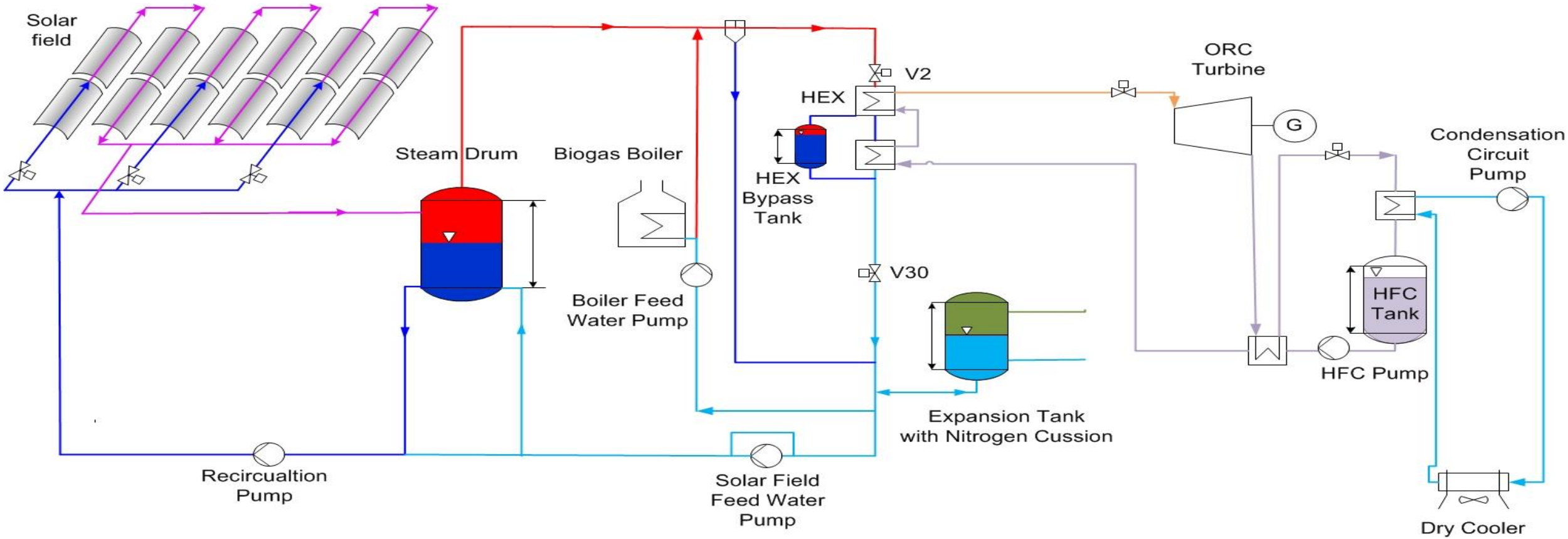
- 1,1 billion people worldwide lack access to electricity,
  - 1,3 billion by 2030 due to population growth
- Mini-grids:
  - Can be faster and more affordable than grid extension
  - Cheapest option for connecting 450 Mio people
- Present trend: retrofitting existing diesel-generators with PV and wind to save fuel
- Why not CSP?
  - CSP-Biomass hybrids
  - 100% dispatchable power from local resources





Source: https://www.weforum.org/agenda/2018/06/1-billion-people-lack-electricity-solution-mini-grid-iea

EU Project ReelCoop: Mini CSP plant scheme



- Direct steam generation (DSG) → ~160-175°C / 6,2-8,9 bar_{abs}
- Recirculation mode
- Closed loop

Solar Field

- 3 Loops, with each 4 parabolic trough collectors =12 collectors
- Robust and simple collector design → Easy installation

Organic Rankine Cycle (ORC) Turbine

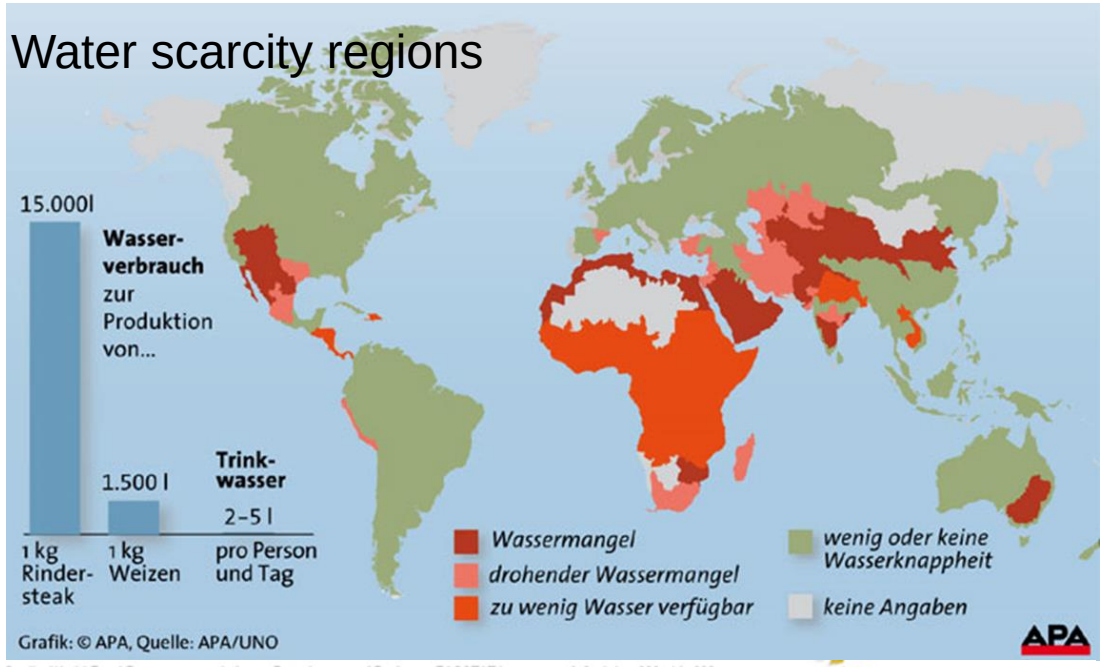
- New generator Design with new winding geometry
- Compact solution → Easy transport and installation at

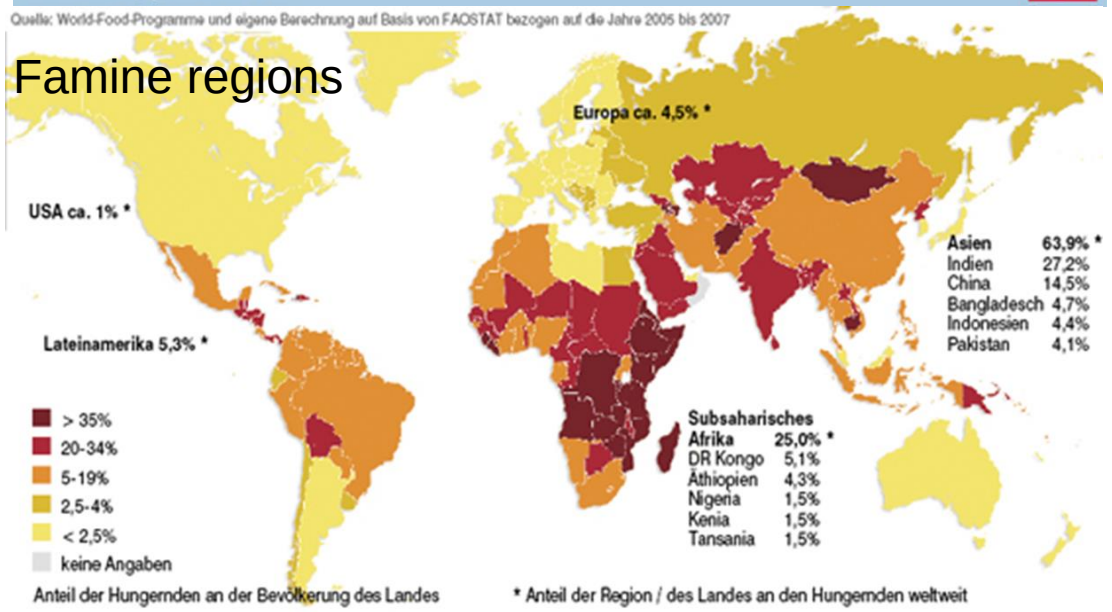
Concept opportunities

- Modular hybrid systems CSP/Biomass boiler
  - Cogeneration to generate additional services
    - electricity, heat, cooling, water treatment
  - Solving local infrastructure problems
    - waste disposal, sewage treatment, water scarcity, harvest losses
  - Creating qualified labour
    - improving local living conditions
    - reducing rural exodus / de-population
  - New business models
    - energy services

- IEA „energy for all“ szenario
  - Mini-grid investment $300 billion until 2030 required

- African food imports $35 billion annually, increasing trend





Concept challenges

- Technological:
  - Interfaces for modular subsystems
  - Common communication and control
  - Variety of applications
  - Cost reduction strategy for small systems
- Political:
  - Overcome instability of relevant regions
  - Education and training
  - Financing programmes
- Cultural
  - Many stakeholders with different background and views

Coordinated effort required

Summary – the DLR vision and mission

- Concentrating solar technologies will significantly contribute to a future renewable energy system.
- DLR mission: R&D to take technologies from basic ideas to large scale demonstration, in cooperation with academia and industry.
- Electricity: Improve competitiveness of utility scale systems, develop solutions for decentralized solutions based on local resources
- High temperature applications: develop and demonstrate production of fuels, chemicals and base materials